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Korva

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(54) **ANTENNA ARRANGEMENT**

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H01Q 21/06 (2006.01)
H01Q 9/04 (2006.01)
H01Q 25/00 (2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 21/065*** (2013.01); ***H01Q 9/0407*** (2013.01); ***H01Q 25/001*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/246; H01Q 1/52; H01Q 9/04; H01Q 9/0414; H01Q 9/0407; H01Q 9/0435; H01Q 9/045; H01Q 9/0457; H01Q 21/06; H01Q 21/061; H01Q 21/065

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,208,660	A	*	6/1980	McOwen, Jr.	H01Q 21/0075 343/789
4,543,579	A		9/1985	Teshirogi	
4,843,400	A	*	6/1989	Tsao	H01Q 21/065 343/700 MS
4,873,529	A		10/1989	Gibson	
5,005,019	A	*	4/1991	Zaghloul	H01Q 9/0414 166/270.1
5,043,738	A	*	8/1991	Shapiro	H01Q 9/0435 343/700 MS
5,055,852	A	*	10/1991	Dusseux	H01Q 9/0414 343/846
5,241,321	A	*	8/1993	Tsao	H01Q 9/0435 343/848

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2 540 216 A1	9/2007
CN	210296621 U	4/2020

(Continued)

OTHER PUBLICATIONS

Chen et al., "High Gain, Broadband and Dual-Polarized Substrate Integrated Waveguide Cavity-Backed Slot Antenna Array for 60 GHz Band", IEEE Access, vol. 6, (Jun. 11, 2018), pp. 31012-31022.

(Continued)

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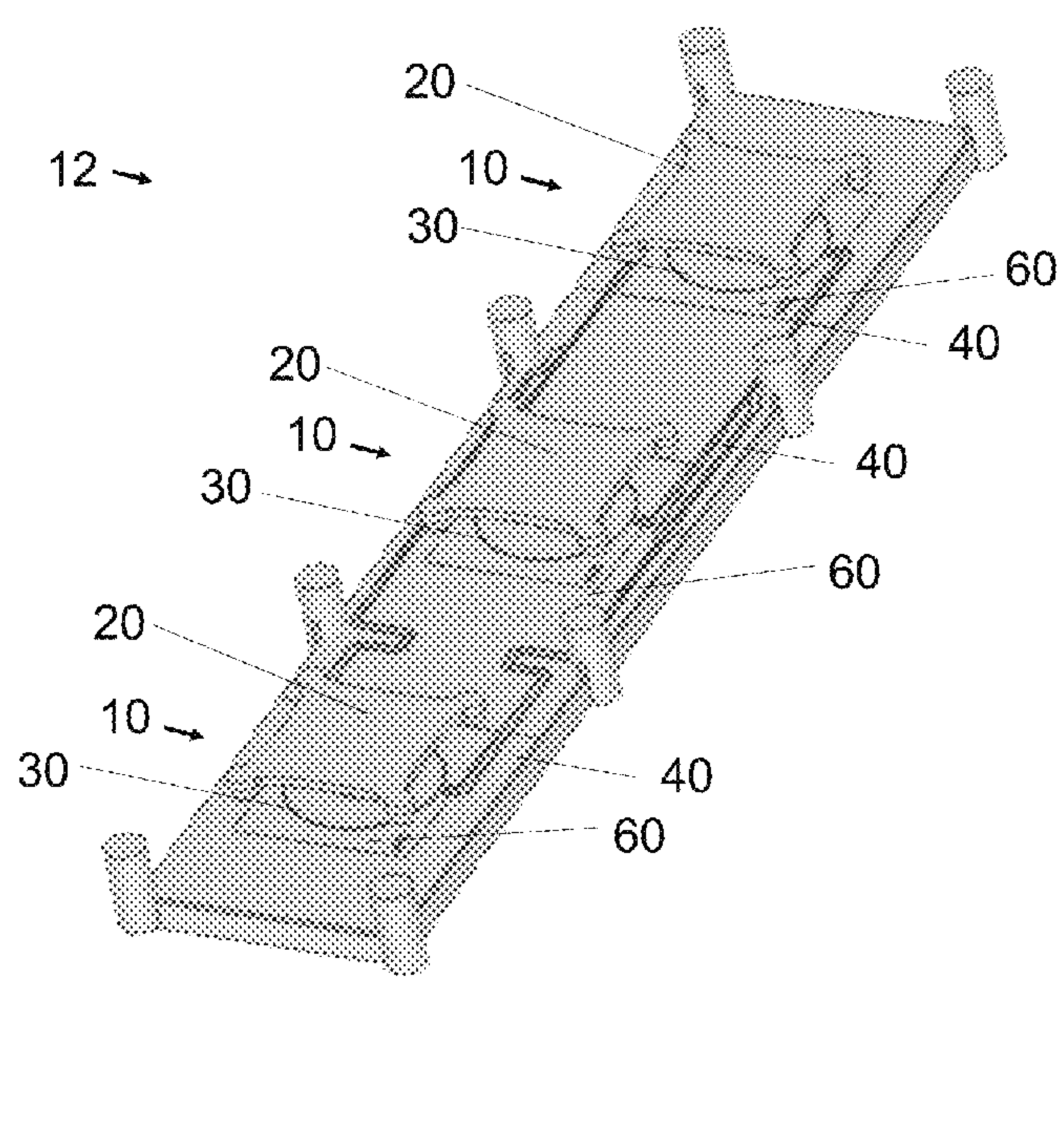
(57) **ABSTRACT**

An antenna arrangement is provided that includes a patch radiator, a feed arrangement, for the patch radiator and a cavity for the feed arrangement. The feed arrangement includes a slot in a conductive layer located between the patch radiator and the cavity.

19 Claims, 4 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,539,420	A *	7/1996	Dusseux	H01Q 9/0414	343/769
5,905,471	A *	5/1999	Biebl	H01Q 1/3275	343/789
6,008,763	A *	12/1999	Nystrom	H01Q 9/0457	343/848
6,054,953	A *	4/2000	Lindmark	H01Q 9/0407	343/846
6,239,750	B1 *	5/2001	Snygg	H01Q 5/40	343/846
6,462,710	B1 *	10/2002	Carson	H01Q 21/065	343/770
6,531,984	B1 *	3/2003	Johannisson	H01Q 9/0435	343/848
7,656,358	B2	2/2010	Haziza		
7,986,279	B2 *	7/2011	Bruno	H01Q 13/18	343/769
9,590,314	B2	3/2017	Celik		
9,929,472	B2 *	3/2018	Rojanski	H01Q 13/10	
10,468,783	B2 *	11/2019	Soodmand	H01Q 9/0428	
2003/0043076	A1 *	3/2003	Carson	H01Q 21/24	343/700 MS
2011/0032164	A1	2/2011	Villarroel et al.		
2013/0044035	A1 *	2/2013	Zhuang	H01Q 9/0428	343/770
2014/0145891	A1 *	5/2014	Palevsky	H01Q 9/0435	343/746
2015/0303576	A1 *	10/2015	Latrach	H01Q 9/0464	343/700 MS
2019/0260115	A1 *	8/2019	Tehran	H01Q 21/065	
2020/0313282	A1 *	10/2020	Jia	H01Q 13/10	
2020/0343648	A1 *	10/2020	Tehran	H01Q 21/06	
2021/0351519	A1 *	11/2021	Korva	H01Q 9/0407	

FOREIGN PATENT DOCUMENTS

EP	1 071 161	A1	1/2001
EP	1357636	A2	10/2003

OTHER PUBLICATIONS

Office Action and Search Report for Finland Application No. 20205470 dated Jan. 22, 2021, 7 pages.

Siddiqui et al., "A Differential Dual-Band Dual-Polarized Antenna for 5G mm Wave Communication System", 2020 2nd 6G Wireless Summit, (Mar. 17-20, 2020), 4 pages.

Extended European Search Report for European Application No. 21172762.3 dated Sep. 24, 2021, 11 pages.

* cited by examiner

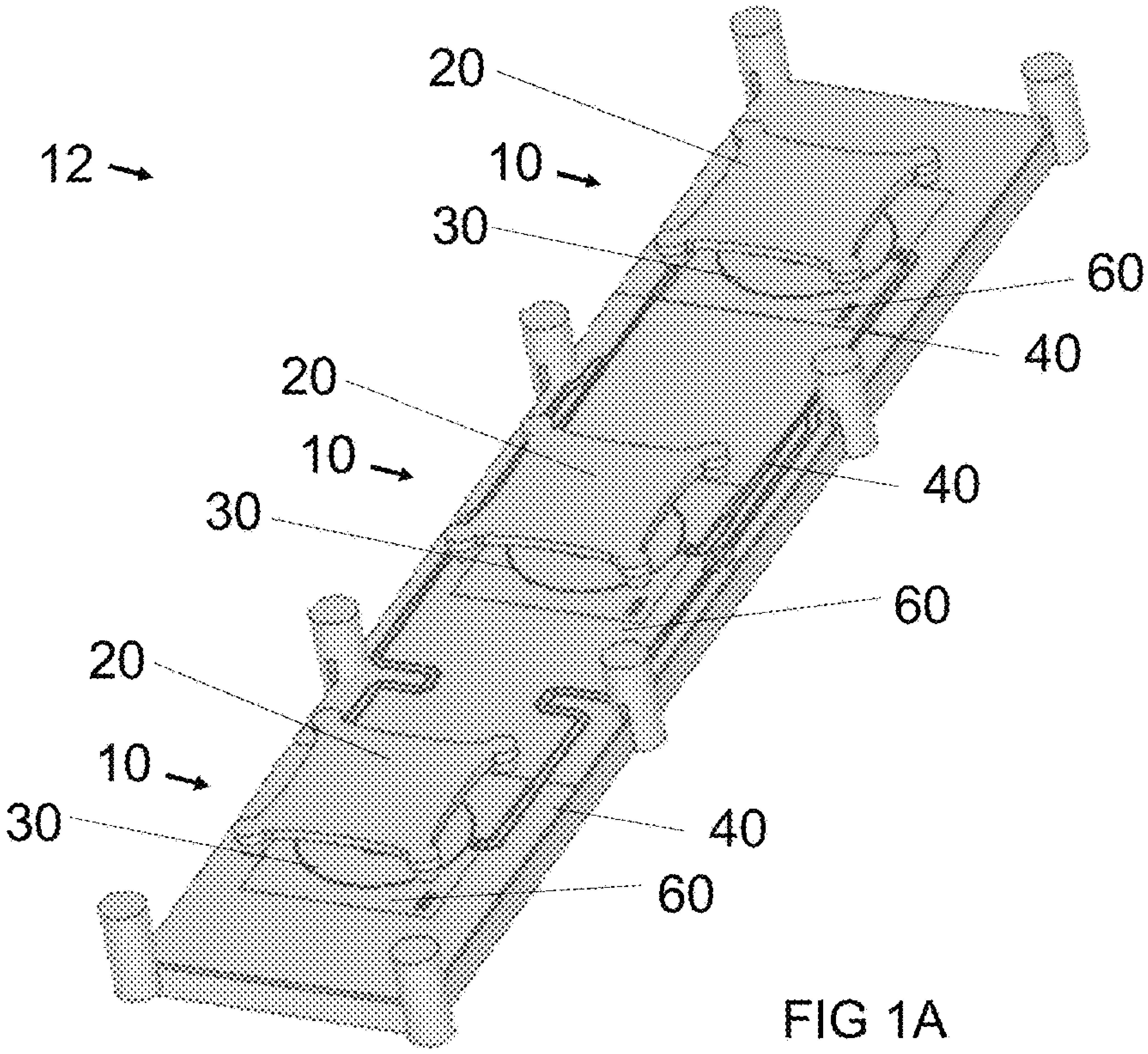


FIG 1A

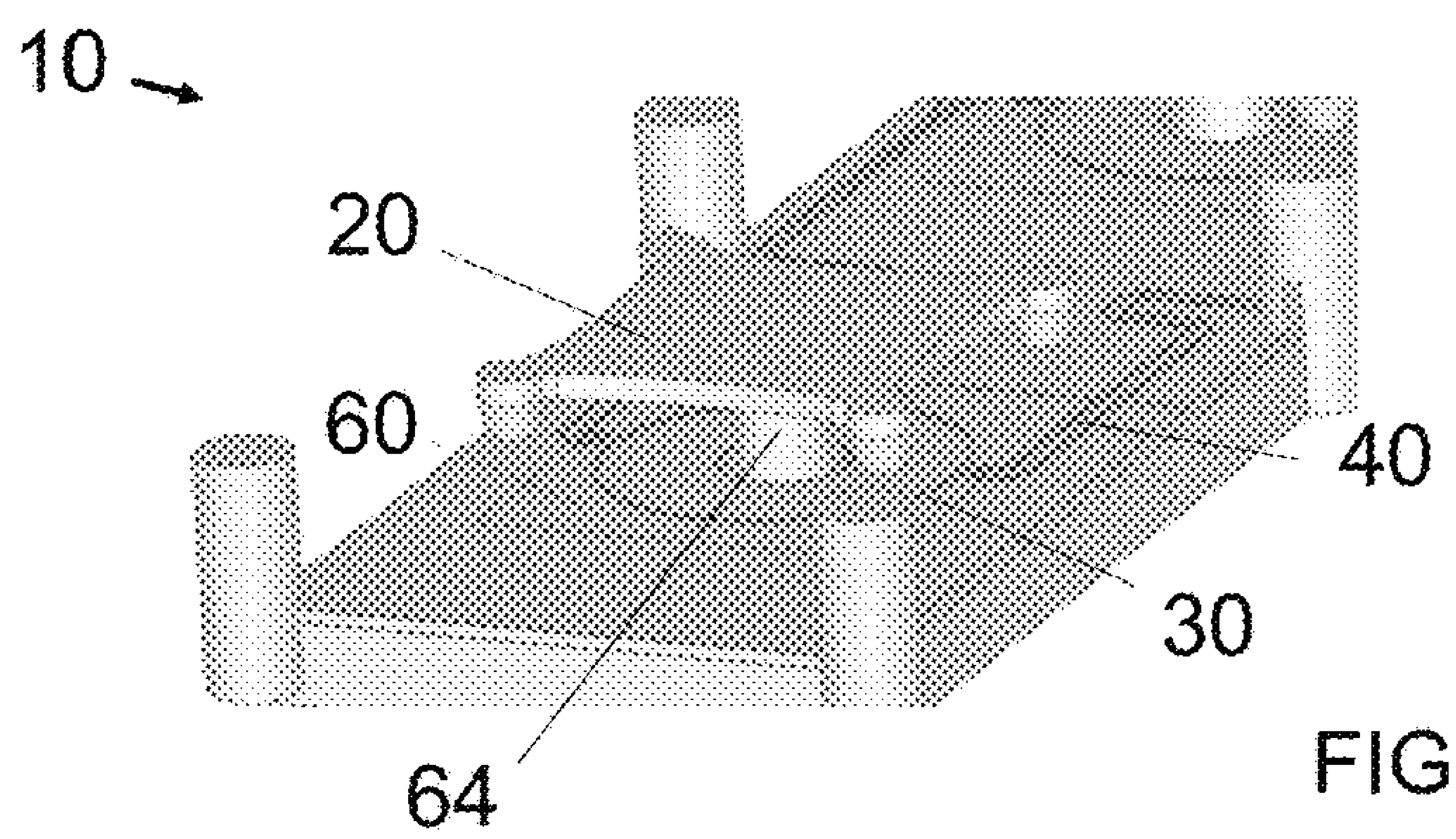


FIG 1B

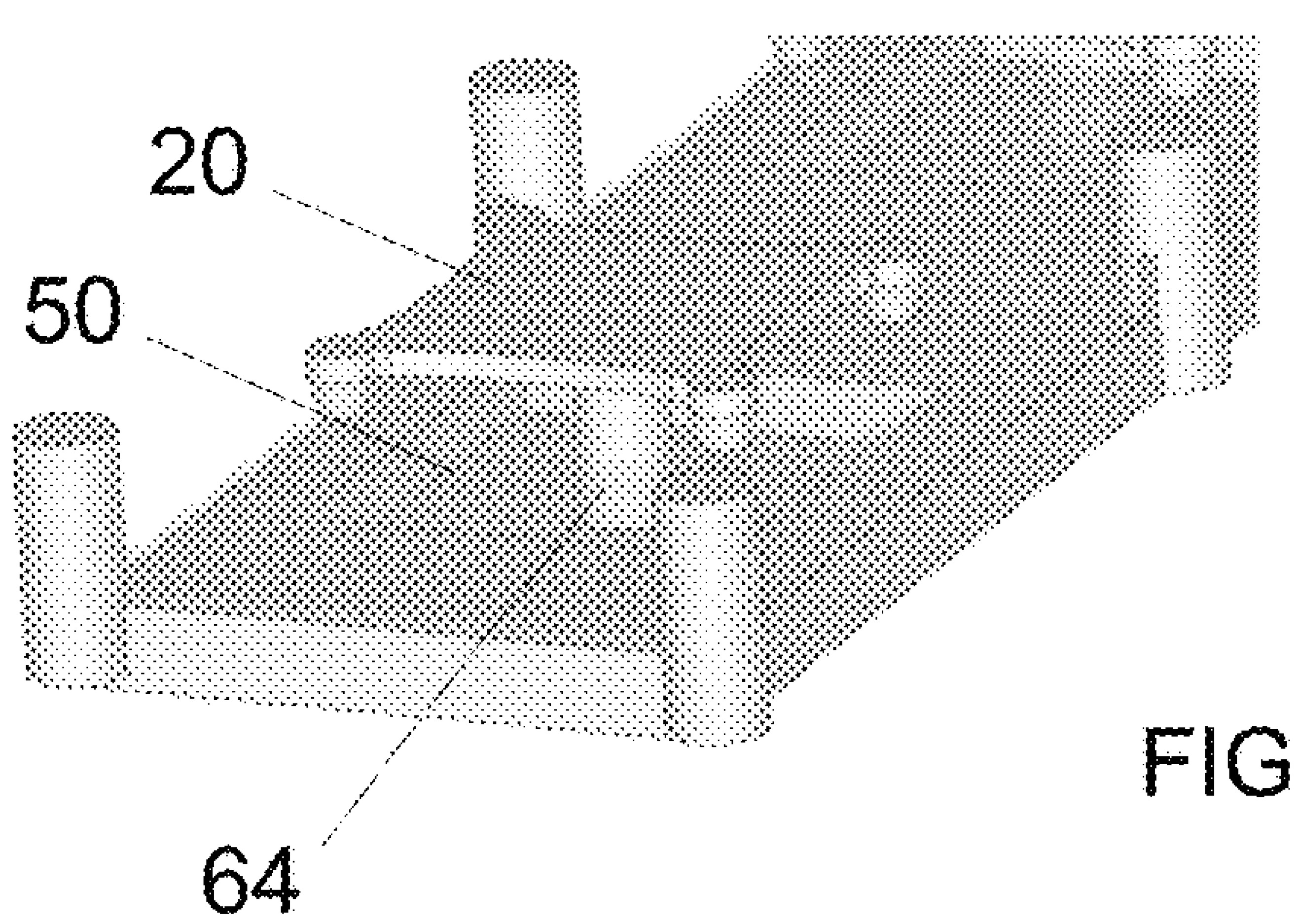


FIG 1C

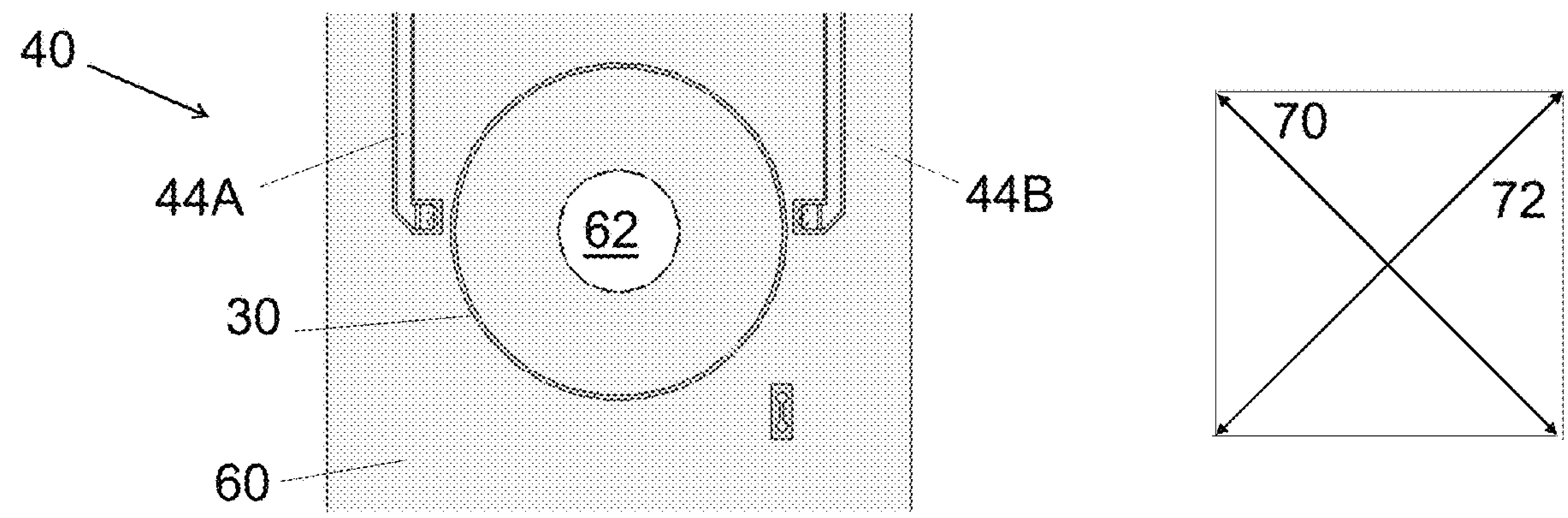


FIG 2A

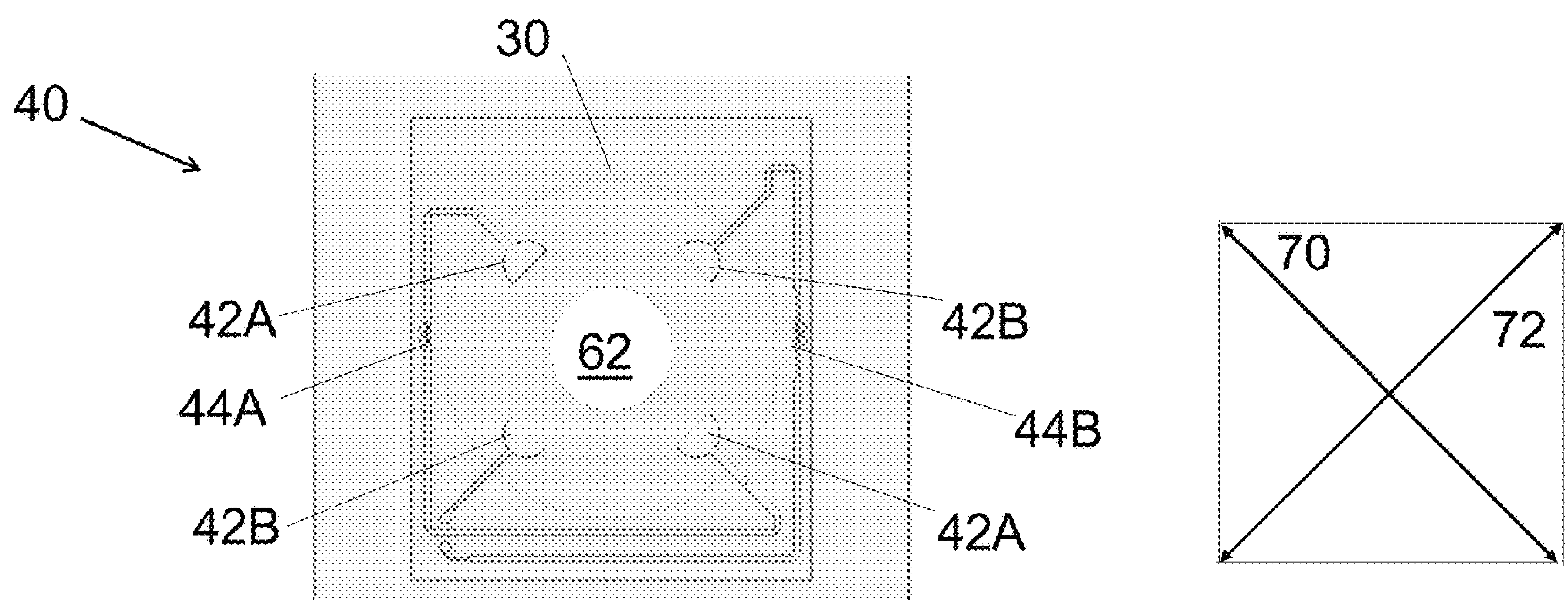


FIG 2B

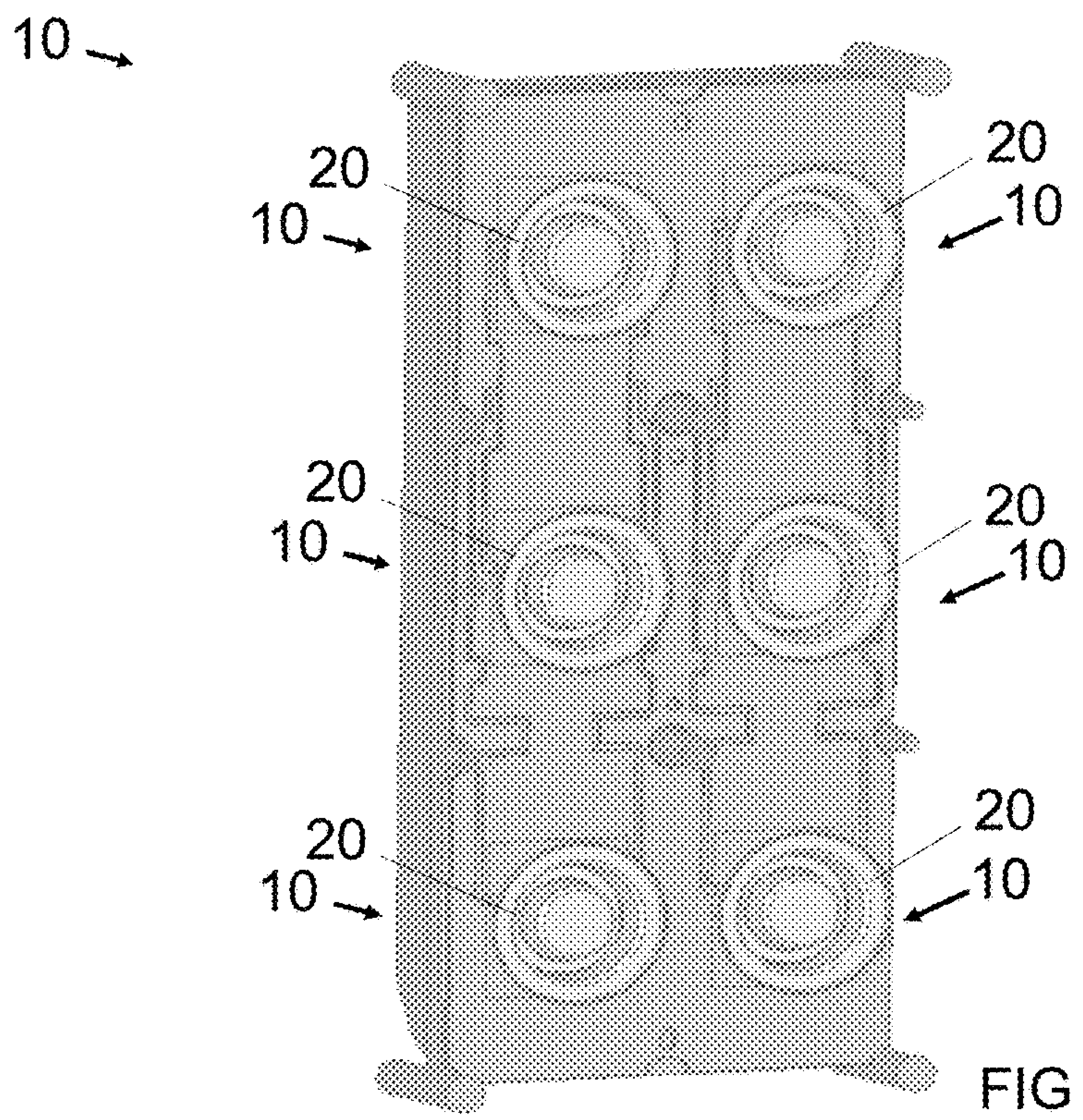

10
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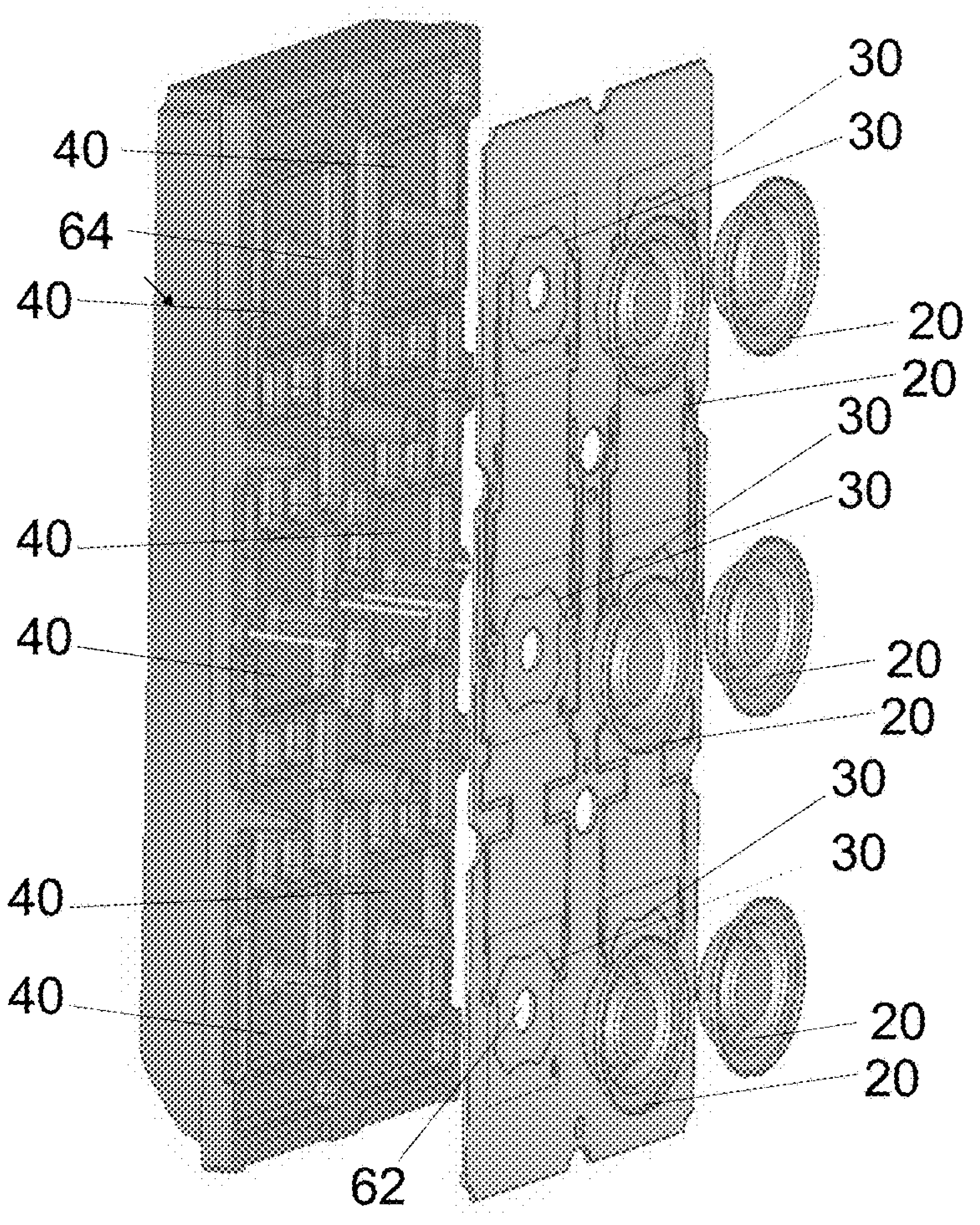
FIG 3A


30
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64
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62
FIG 3B

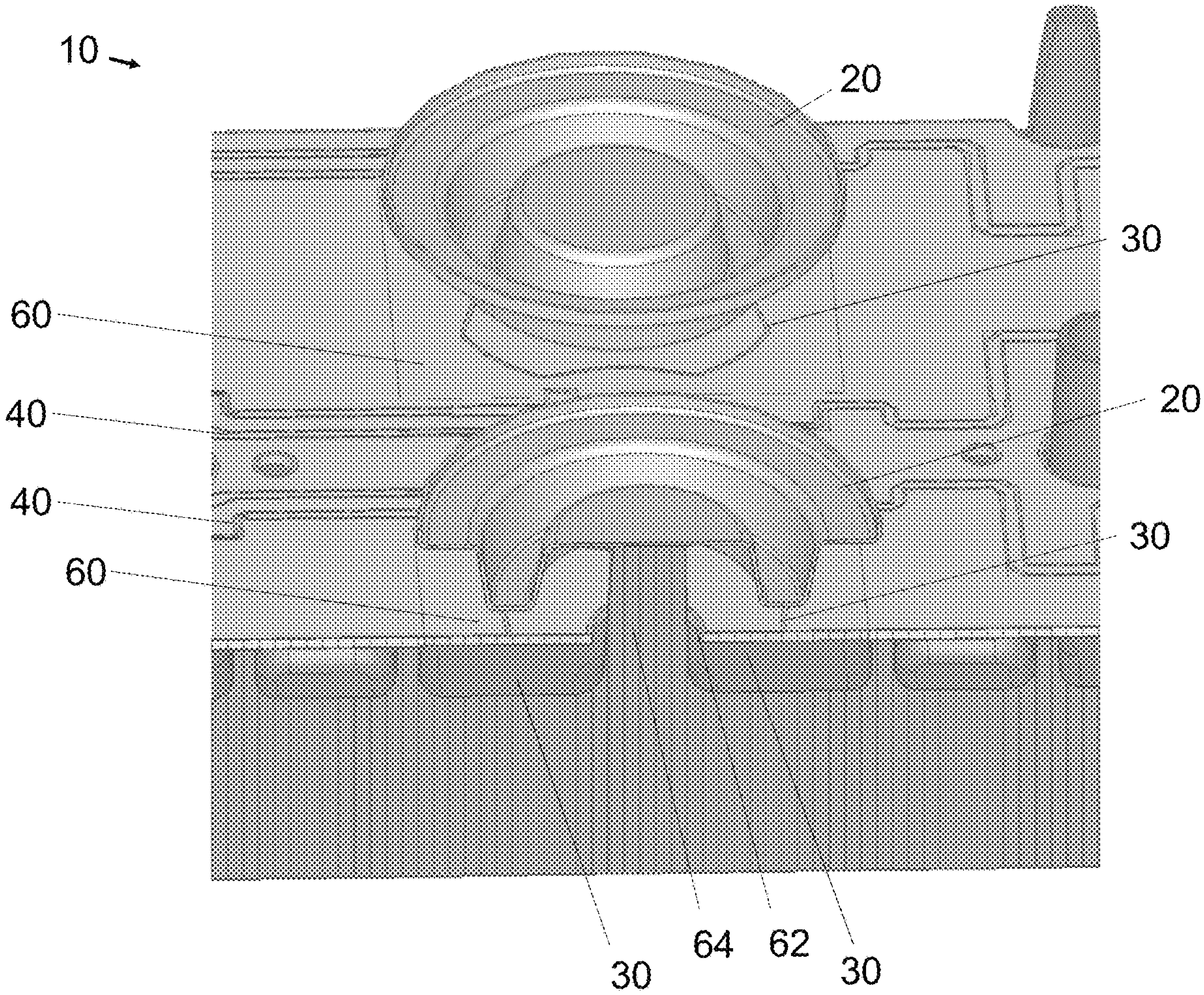

FIG 4

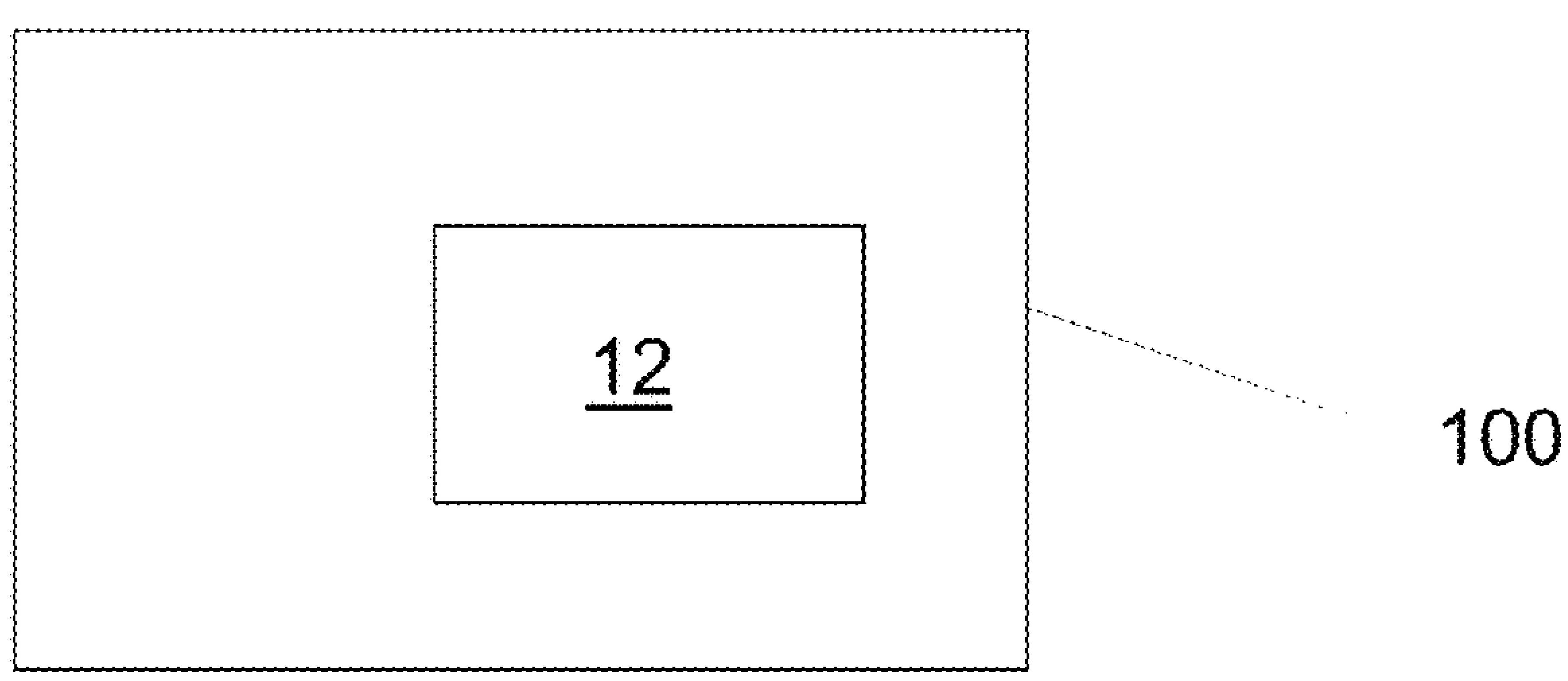

FIG 5

ANTENNA ARRANGEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Finnish Application No. 20205470, filed May 11, 2020, the entire contents of which are incorporated herein by reference.

TECHNOLOGICAL FIELD

Embodiments of the present disclosure relate to an antenna arrangement. Some relate to a dual linear-polarized antenna arrangement.

BACKGROUND

Dual linear-polarized antenna arrangements often comprise a first dipole radiator oriented in a first polarization direction and a second dipole radiator oriented in a second polarization direction which is orthogonal to the first polarization direction.

It can be difficult to simultaneously optimize the antenna arrangement so that S-parameters have a suitably large bandwidth at a target frequency and there is sufficient isolation between the radiators.

The problem can be even greater in arrays of dual linear-polarized antenna arrangements that are use for beam steering, as sufficient isolation needs to be maintained across a range of beam steering angles.

BRIEF SUMMARY

According to various, but not necessarily all, embodiments there is provided an antenna arrangement comprising:

a patch radiator;

a feed arrangement, for the patch radiator; and

a cavity for the feed arrangement, wherein

the feed arrangement comprises a slot in a conductive layer located between the patch radiator and the cavity.

In some but not necessarily all examples, the feed arrangement comprises at least two feed conductors arranged adjacent the conductive layer wherein each of the feed conductors extend over different portions of the slot.

In some but not necessarily all examples, the feed conductors extends across the slot in a direction perpendicular to the slot, and wherein the feed conductors have different orientations

In some but not necessarily all examples, the feed conductors have different orientations that are mutually offset by 90°.

In some but not necessarily all examples, the slot is galvanically separated from the patch radiator.

In some but not necessarily all examples, the feed arrangement comprises a first pair of feed conductors that extend over different portions of the slot, are aligned and are oriented in a first direction and wherein the feed arrangement comprises a second pair of feed conductors that extend over different portions of the slot, are aligned and are oriented in a second direction that is orthogonal to the first direction.

In some but not necessarily all examples, the feed arrangement is a balanced feed arrangement wherein at an operational frequency band, conductive interconnects to the first pair of feed conductors, of different lengths, introduce a 180° phase difference between the first pair of feed conductors which are connected as open-circuit and conductive interconnects to the second pair of feed conductors, of different lengths, introduce a 180° phase difference between the second pair of feed conductors.

In some but not necessarily all examples, the conductive layer is planar.

In some but not necessarily all examples, the slot is an elongate slot that forms a closed loop.

In some but not necessarily all examples, the slot is sinuous comprising multiple bends of different handedness.

In some but not necessarily all examples, the patch radiator is rotationally symmetric.

In some but not necessarily all examples, the patch radiator has a first dimension in a first direction that corresponds to half a wavelength at an operational frequency band of the antenna arrangement and has a second dimension in a second direction that corresponds to half a wavelength at the operational frequency band of the antenna arrangement.

In some but not necessarily all examples, the patch radiator has a three-dimensional shape.

In some but not necessarily all examples, one of an exterior perimeter of the patch radiator and an exterior perimeter of the slot are circular.

In some but not necessarily all examples, a base station comprises an array of antenna arrangements.

According to various, but not necessarily all, embodiments there is provided examples as claimed in the appended claims.

BRIEF DESCRIPTION

Some examples will now be described with reference to the accompanying drawings in which:

FIG. **1**A shows an example of the subject matter described herein;

FIG. **1**B shows another example of the subject matter described herein;

FIG. **1**C shows another example of the subject matter described herein;

FIG. **2**A shows another example of the subject matter described herein;

FIG. **2**B shows another example of the subject matter described herein;

FIG. **3**A shows another example of the subject matter described herein;

FIG. **3**B shows another example of the subject matter described herein;

FIG. **4** shows another example of the subject matter described herein; and

FIG. **5** shows another example of the subject matter described herein.

DETAILED DESCRIPTION

The FIGs illustrate examples of an antenna arrangement **10** comprising:

a patch radiator **20**; a feed arrangement **40**, for the patch radiator **20**; and

a cavity **50** for the feed arrangement **40**.

The feed arrangement **40** comprises a slot **30** in a conductive layer **60**. The slot **30** is located between the patch radiator **20** and the cavity **50**.

The slot **30** is a through aperture that extends through the conductive layer **60**. The slot is an elongate aperture. It is much longer than it is wide.

The antenna arrangement **10** can be used for transmission of far field radio waves and/or reception of far field radio waves.

In some examples, an antenna system **12** comprises an array **12** of antenna arrangements **10**.

FIG. **1**A illustrates, in perspective view, an array **12** of antenna arrangements **10**. FIG. **1**B illustrates one of those antenna arrangements **10**. FIG. **1**B illustrates the antenna arrangement **10** of FIG. **1**B without the conductive layer **60**, exposing the cavity **50**.

FIGS. **2**A and **2**B illustrate a feed arrangement **40** suitable for an antenna arrangement **10**, for example, the antenna arrangement **10** of FIG. **1**B. FIG. **2**A and FIG. **2**B illustrate opposing sides of the conductive layer **60**.

FIG. **3**A illustrates, in perspective view, another array **12** of antenna arrangements **10**. FIG. **3**B illustrates an exploded view of the array **12** of antenna arrangements **10** illustrated in FIG. **3**A. FIG. **4** illustrates in perspective cross-sectional view one of the antenna arrangements **10** of FIGS. **3**A and **3**B.

FIG. **5** illustrates a base station **100** that comprises an array **12** of antenna arrangements **10**.

In these examples, the antenna arrangements **10** have dual linear polarization. The feed arrangement **40** is dual polarized and comprises at least two feed conductors **42**A, **42**B one for each orthogonal linear polarization. The feed conductors **42**A, **42**B are arranged adjacent the conductive layer **60**. As illustrated in FIGS. **2**A and **2**B each of the feed conductors **42**A, **42**B extends over different portions of the slot **30**. The feed conductors **42**A, **42**B overlap the slot and extend across both an exterior perimeter of the slot and an interior perimeter of the slot.

In some but not necessarily all examples, the feed conductors **42**A, **42**B extends across the slot **30** in a direction perpendicular to the slot **30**. However, other angles may be possible.

In some but not necessarily all examples, the feed conductors **42**A, **42**B have different orientations that are mutually offset by 90°.

In the examples illustrated, the feed arrangement **40** comprises a first pair of feed conductors **42**A that extend over different opposing portions of the slot **30**. The first pair of feed conductors **42**A are aligned and are oriented in a first direction **70**. The feed arrangement **40** also comprises a second pair of feed conductors **42**B that extend over different opposing portions of the slot **30**. The second pair of feed conductors **42**B are aligned and are oriented in a second direction **72** that is orthogonal to the first direction **70**.

The feed arrangement **40** can be a balanced feed arrangement **40**. First conductive interconnects **44**A couple to the first pair of feed conductors **42**A. The first conductive interconnects **44**A are of different physical (and electrical) length, and are configured to introduce, at an operational frequency band, a 180° phase difference between the first pair of feed conductors **42**A. Each of the first pair of feed conductors **42**A can terminate in an open-circuit impedance (high impedance). Second conductive interconnects **44**B couple to the second pair of feed conductors **42**B. The second conductive interconnects **44**B are of different physical (and electrical) length, and are configured to introduce, at the operational frequency band, a 180° phase difference between the second pair of feed conductors **42**B which are connected as open-circuit.

This balanced feed, for each of the dual linear polarizations, provides better isolation between the polarizations.

The conductive layer **60** can be grounded (earthed) and form a ground plane. The conductive layer **60** can be a ground plane or part of a larger ground plane.

The conductive layer **60** can for example be provided as a planar layer and can be supported by a dielectric substrate.

The conductive layer **60** can for example be provided as a printed circuit board (PCB).

In the example, illustrated in FIGS. **2**A and **2**B, a single first conductive interconnect **44**A travels along one side of the PCB (FIG. **2**A), then travels through a via in the PCB to the other side of the PCB where (FIG. **2**B) it splits to provide the first conductive interconnects **44**A of different lengths to the respective first pair of feed conductors **42**A. Also a single second conductive interconnect **44**B travels along one side of the PCB (FIG. **2**A), then travels through a via in the PCB to the other side of the PCB where (FIG. **2**B) it splits to provide the second conductive interconnects **44**B of different lengths to the respective second pair of feed conductors **42**B.

In some but not necessarily all examples, the side of the PCB that comprises the pairs of feed conductors **42**A, **42**B is the side furthest from the patch radiator **20** as is within the cavity **50**.

The patch radiator **20** is slot-fed by the slot **30**. The slot **30** itself radiates from beneath the patch radiator **20** to feed the patch radiator **20**. This avoids soldering.

The slot **30** is long and narrow and curves round on its self to form a closed loop. In the examples illustrated, the slot has a constant width along its length. Its length is greater than **30** times its width.

The slot **30** has rotational symmetry. In the examples illustrated it has a shape with at least four degrees of rotational symmetry. That is, it is isomorphic under a rotation of 90° about a central point.

The patch radiator **20** is formed from conductive material. It can for example be formed from metal or from non-conductive substrate covered in conductive material. The non-conductive substrate can for example be formed from a non-conductive dielectric material, for example at least one of: plastic, FR4 PCB material, ceramic material, and other known RF-suitable dielectric materials.

The patch radiator **20** has rotational symmetry. In the examples illustrated it has a shape with at least four degrees of rotational symmetry. That it is isomorphic under a rotation of 90° about a central point.

The patch radiator **20** is sized to operate at an operational frequency band. It has a first dimension in the first direction **70** that corresponds to half a wavelength at the operational frequency band of the antenna arrangement **10** and has a second dimension in the second direction **72** that corresponds to half a wavelength at the operational frequency band of the antenna arrangement **10**. The size of the first dimension and the second dimension can be the same.

The patch radiator **20** is supported by a support **64** that extends through an aperture **62** in the conductive layer **60** at a central location within an inner perimeter of the slot **30**.

The support **64** in the examples illustrated is a post that extends upwards from a base of the cavity **50**. It is connected to the center of the patch radiator **20**. This connection can be galvanic (electrically conductive of direct current) or isolated (electrically insulated). The support **64** can for example be formed from a block of conductive material, such as metal that has material removed to form the cavity **50**. The centre position of the support with respect to the patch radiator **20** grounds the patch radiator but, because of its central location, in a way that does not affect the operation of the patch radiator **20**.

The cavity **50** is a grounded conductive cavity. It can, for example, be formed in a metal or conductive base. The base can, for example, be formed from die cast aluminium. Alternatively, the cavity can be formed by coating a non-conductive substrate in conductive material. The non-conductive substrate can for example be formed from a non-conductive dielectric material, for example at least one of: plastic, FR4 PCB material, ceramic material, and other known RF-suitable dielectric materials. In some examples, stacked PCBs could be used to define the cavity **50**. A lower grounded PCB could, for example, provide a base of the cavity **50**. Upper grounded PCB or PCBs, which is/are stacked on top of the lower PCB and affixed thereto, could have a cut-out area that defines the sidewalls of the cavity **50** by creating a via.

The patch radiator **20** can enclose the cavity **50**.

The cavity **50** can be sized and shaped to operate as a reflector for the slot **30**. There can, for example, be a distinct cavity **50** for each slot **30**.

The cavity **50** is relatively shallow. It can for example have a depth between ⅛ and ¼ of a wavelength at the operational frequency band of the antenna arrangement **10**. This may correspond to a depth of a few mm in some examples.

In the FIGs, the example illustrated in FIGS. **1**A, **1**B, **1**C and the example illustrated in FIGS. **3**A, **3**B, **4** have some common properties as described above.

Also, in each of the examples, one of the patch radiator **20** and the slot **30** has an exterior perimeter that is circular and the other one of the patch radiator **20** and the slot **30** has an exterior perimeter that has four degrees of rotational symmetry.

In the example illustrated in FIGS. **1**A, **1**B, **1**C the slot **30** has an exterior (and interior) perimeter that is circular and the patch radiator **20** has an exterior perimeter that is non-circular and has four degrees of rotational symmetry. In this example, the patch radiator is a two-dimensional shape being shaped in two-dimensions but not the third dimension.

In the example illustrated in FIGS. **3**A, **3**B, **4** the patch radiator **20** has an exterior perimeter that is circular and the slot **30** has an exterior (and interior) perimeter that is non-circular and has four degrees of rotational symmetry. In this example, patch radiator **20** is a three-dimensional shape. The slot **30** lies in a two-dimensional plane. The slot **30** is sinuous comprising multiple bends of different, alternating handedness. This allows a greater length of slot **30** to enclose a smaller area. The curved/meandering shape of the closed-loop slot **30** provides sufficient electrical length at the operational frequency band to achieve isolation between feed conductors **42**A, **42**B.

FIG. **5** illustrates an example of a base station comprising an antenna arrangement **10**, for example, it can comprise an array **12** of antenna arrangements **10** as previously described.

The array **12** of antenna arrangements **10** can in some examples be configured for operation as active antennas that perform digital beamforming and beam steering. The array **12** of antenna arrangements **10** is suitable for massive multiple-input multiple-output (mMIMO) operation.

The array **12** of antenna arrangements **10** can in some examples be configured for digital beam steering at a wide operational bandwidth below 6 GHz. The beam steering can, for example, steer at least +/−60° from the boresight in the azimuthal (horizontal) direction and at least +/10° from the boresight in the polar (vertical) direction.

The cross-polar discrimination can, for example, be >20 dB at boresight and >10 dB over the whole steering range.

The antenna arrangements **10** described have good side lobe suppression at extreme steering angles because the antenna arrangements **10** have wide half power beamwidth. This same array gain can be obtained on sector edges with less beamsteering.

Where a structural feature has been described, it may be replaced by means for performing one or more of the functions of the structural feature whether that function or those functions are explicitly or implicitly described.

The operational frequency band may be within or cover a low band (0.7 to 0.96 GHz), a high band (1.7 to 2.7 GHz) or a very high band (3.3 to 3.8 GHz).

The operational frequency band may be within or cover 400-10 GHz. The operational frequency band may be within or cover 2500-2690 MHz. The operational frequency band may be within or cover 3400-3800 MHz.

The operational frequency bands, for example the first frequency band, the second frequency band and the third frequency band may be within or cover (but are not limited to) Long Term Evolution (LTE) (US) (734 to 746 MHz and 869 to 894 MHz), Long Term Evolution (LTE) (rest of the world) (791 to 821 MHz and 925 to 960 MHz), amplitude modulation (AM) radio (0.535-1.705 MHz); frequency modulation (FM) radio (76-108 MHz); Bluetooth (2400-2483.5 MHz); wireless local area network (WLAN) (2400-2483.5 MHz); hiper local area network (HiperLAN) (5150-5850 MHz); global positioning system (GPS) (1570.42-1580.42 MHz); US—Global system for mobile communications (US-GSM) 850 (824-894 MHz) and 1900 (1850-1990 MHz); European global system for mobile communications (EGSM) 900 (880-960 MHz) and 1800 (1710-1880 MHz); European wideband code division multiple access (EU-WCDMA) 900 (880-960 MHz); personal communications network (PCN/DCS) 1800 (1710-1880 MHz); US wideband code division multiple access (US-WCDMA) 1700 (transmit: 1710 to 1755 MHz, receive: 2110 to 2155 MHz) and 1900 (1850-1990 MHz); wideband code division multiple access (WCDMA) 2100 (transmit: 1920-1980 MHz, receive: 2110-2180 MHz); personal communications service (PCS) 1900 (1850-1990 MHz); time division synchronous code division multiple access (TD-SCDMA) (1900 MHz to 1920 MHz, 2010 MHz to 2025 MHz), ultra wideband (UWB) Lower (3100-4900 MHz); UWB Upper (6000-10600 MHz); digital video broadcasting—handheld (DVB-H) (470-702 MHz); DVB-H US (1670-1675 MHz); digital radio mondiale (DRM) (0.15-30 MHz); worldwide interoperability for microwave access (WiMax) (2300-2400 MHz, 2305-2360 MHz, 2496-2690 MHz, 3300-3400 MHz, 3400-3800 MHz, 5250-5875 MHz); digital audio broadcasting (DAB) (174.928-239.2 MHz, 1452.96-1490.62 MHz); radio frequency identification low frequency (RFID LF) (0.125-0.134 MHz); radio frequency identification high frequency (RFID HF) (13.56-13.56 MHz); radio frequency identification ultra high frequency (RFID UHF) (433 MHz, 865-956 MHz, 2450 MHz) and frequency bands for 5G.

A frequency band over which an antenna can efficiently operate is a frequency range where the antenna's return loss is less than an operational threshold **64**. For example, efficient operation may occur when the antenna's return loss S**11** is better than (that is, less than) −15 dB.

An operational bandwidth may be defined as where the return loss S**11** is better than an operational threshold T such as, for example, −15 dB.

As used here 'module' refers to a unit or apparatus that excludes certain parts/components that would be added by an end manufacturer or a user.

The array **12** of antenna arrangements **10** can be a module. An antenna arrangement **10** can be a module.

The above described examples find application as enabling components of:

automotive systems; telecommunication systems; electronic systems including consumer electronic products; distributed computing systems; media systems for generating or rendering media content including audio, visual and audio visual content and mixed, mediated, virtual and/or augmented reality; personal systems including personal health systems or personal fitness systems; navigation systems; user interfaces also known as human machine interfaces; networks including cellular, non-cellular, and optical networks; ad-hoc networks; the internet; the internet of things; virtualized networks; and related software and services.

The term 'comprise' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one Y or may comprise more than one Y. If it is intended to use 'comprise' with an exclusive meaning then it will be made clear in the context by referring to "comprising only one . . ." or by using "consisting".

In this description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'can' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example', 'can' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example as part of a working combination but does not necessarily have to be used in that other example.

Although examples have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the claims.

Features described in the preceding description may be used in combinations other than the combinations explicitly described above.

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain examples, those features may also be present in other examples whether described or not.

The term 'a' or 'the' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising a/the Y indicates that X may comprise only one Y or may comprise more than one Y unless the context clearly indicates the contrary. If it is intended to use 'a' or 'the' with an exclusive meaning then it will be made clear in the context. In some circumstances the use of 'at least one' or 'one or more' may be used to emphasis an inclusive meaning but the absence of these terms should not be taken to infer any exclusive meaning.

The presence of a feature (or combination of features) in a claim is a reference to that feature or (combination of features) itself and also to features that achieve substantially the same technical effect (equivalent features). The equivalent features include, for example, features that are variants and achieve substantially the same result in substantially the same way. The equivalent features include, for example, features that perform substantially the same function, in substantially the same way to achieve substantially the same result.

In this description, reference has been made to various examples using adjectives or adjectival phrases to describe characteristics of the examples. Such a description of a characteristic in relation to an example indicates that the characteristic is present in some examples exactly as described and is present in other examples substantially as described.

Whilst endeavoring in the foregoing specification to draw attention to those features believed to be of importance it should be understood that the Applicant may seek protection via the claims in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not emphasis has been placed thereon.

I claim:

1. An antenna arrangement comprising:

a patch radiator;

a feed arrangement, for the patch radiator; and

a cavity for the feed arrangement,

wherein the feed arrangement comprises an elongate slot, forming a closed loop, in a conductive layer located between the patch radiator and the cavity, and wherein the slot is sinuous comprising multiple bends of different handedness.

2. An antenna arrangement as claimed in claim **1**, wherein the feed arrangement comprises at least two feed conductors arranged adjacent the conductive layer wherein each of the feed conductors extend over different portions of the slot.

3. An antenna arrangement as claimed in claim **2**, wherein the feed conductors extends across the slot in a direction perpendicular to the slot, and wherein the feed conductors have different orientations.

4. An antenna arrangement as claimed in claim **2**, wherein the feed conductors have different orientations that are mutually offset by 90°.

5. An antenna arrangement as claimed in claim **1**, wherein the slot is galvanically separated from the patch radiator.

6. An antenna arrangement as claimed in claim **1**, wherein the feed arrangement comprises a first pair of feed conductors that extend over different portions of the slot, are aligned and are oriented in a first direction and wherein the feed arrangement comprises a second pair of feed conductors that extend over different portions of the slot, are aligned and are oriented in a second direction that is orthogonal to the first direction.

7. An antenna arrangement as claimed in claim **6**, wherein the feed arrangement is a balanced feed arrangement wherein at an operational frequency band, conductive interconnects to the first pair of feed conductors, of different lengths, introduce a 180° phase difference between the first pair of feed conductors which are connected as open-circuit and conductive interconnects to the second pair of feed conductors, of different lengths, introduce a 180° phase difference between the second pair of feed conductors.

8. An antenna arrangement as claimed in claim **1**, wherein the conductive layer is planar.

9. An antenna arrangement as claimed in claim **1**, wherein the patch radiator is rotationally symmetric.

10. An antenna arrangement as claimed in claim **1**, wherein the patch radiator has a first dimension in a first direction that corresponds to half a wavelength at an operational frequency band of the antenna arrangement and has a second dimension in a second direction that corresponds to half a wavelength at the operational frequency band of the antenna arrangement.

11. An antenna arrangement as claimed in claim **1**, wherein the patch radiator has a three-dimensional shape.

12. An antenna arrangement as claimed in claim **1**, wherein one of an exterior perimeter of the patch radiator and an exterior perimeter of the slot are circular.

13. A base station comprising an array of antenna arrangements, wherein

at least one of the array or antenna arrangements comprises:

a patch radiator;

a feed arrangement, for the patch radiator; and

a cavity for the feed arrangement,

wherein the feed arrangement comprises an elongate slot, forming a closed loop, in a conductive layer located between the patch radiator and the cavity, and wherein the slot is sinuous comprising multiple bends of different handedness.

14. A base station as claimed in claim **13**, wherein the feed arrangement of the at least one of the array of antenna arrangements comprises at least two feed conductors arranged adjacent the conductive layer, and wherein each of the feed conductors extend over different portions of the slot.

15. A base station as claimed in claim **13**, wherein the feed arrangement of the at least one of the array of antenna arrangements comprises a first pair of feed conductors that extend over different portions of the slot, are aligned and are oriented in a first direction and wherein the feed arrangement comprises a second pair of feed conductors that extend over different portions of the slot, are aligned and are oriented in a second direction that is orthogonal to the first direction.

16. A base station as claimed in claim **15**, wherein the feed arrangement is a balanced feed arrangement wherein at an operational frequency band, conductive interconnects to the first pair of feed conductors, of different lengths, introduce a 180° phase difference between the first pair of feed conductors which are connected as open-circuit and conductive interconnects to the second pair of feed conductors, of different lengths, introduce a 180° phase difference between the second pair of feed conductors.

17. A base station as claimed in claim **13**, wherein the patch radiator of the at least one of the array of antenna arrangements has a first dimension in a first direction that corresponds to half a wavelength at an operational frequency band of the at least one of the array of antenna arrangements and has a second dimension in a second direction that corresponds to half a wavelength at the operational frequency band of the at least one of the array of antenna arrangements.

18. A base station as claimed in claim **13**, wherein one of an exterior perimeter of the patch radiator and an exterior perimeter of the slot are circular.

19. An antenna arrangement comprising:

a patch radiator;

a feed arrangement for the patch radiator; and

a cavity for the feed arrangement,

wherein the feed arrangement comprises a slot in a conductive layer located between the patch radiator and the cavity,

wherein the feed arrangement comprises (i) a first pair of feed conductors, of different lengths, that extend over different portions of the slot, and are aligned and oriented in a first direction and (ii) a second pair of feed conductors, of different lengths, that extend over different portions of the slot, and are aligned and oriented in a second direction that is orthogonal to the first direction,

wherein the feed arrangement comprises a balanced feed arrangement, and

wherein at an operational frequency band, conductive interconnects to the first pair of feed conductors introduce a 180° phase difference between the first pair of feed conductors, which are connected as open-circuit, and conductive interconnects to the second pair of feed conductors introduce a 180° phase difference between the second pair of feed conductors.

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